METHOD AND APPARATUS FOR GENERATING REFERENCE TRANSMISSION SIGNAL FOR USE IN TESTING COMMUNICATIONS RECEIVERS

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to test equipment for communications receivers, and in particular, to methods for generating test signals for complex digital communications systems.

2. Description of the Related Art

[0002] Requirements for modern test equipment have become increasingly advanced, since testing generally no longer involve small subsystems, but complete, and increasingly complex, systems. As a result, it is often necessary to generate complex test signals, particularly for digital communications equipment, to sufficiently exercise the functions and capabilities of the device under test (DUT). Many systems, including those implemented in integrated circuits and often referred to as a "system on a chip" (SOC), have many different test modes. Accordingly, implementing all such test modes in hardware in any given piece of test equipment is not practical. Hence, test equipment vendors more often provide software solutions to enable the user of the test equipment to generate customized test signals (often referred to as data packages). These software solutions often require significant knowledge on the part of the users, thereby necessitating significant training and learning for using the software. Furthermore, such software solutions are often very expensive and are usually overkill in the sense that many applications require relatively few and relatively simple tests,

such as receiver sensitivity, as opposed to complex testing, such as the effects of specific bit errors.

SUMMARY OF THE INVENTION

[0003] In accordance with the presently claimed invention, a data packet transmission signal containing a plurality of reference data is captured and digitized, following which reference data is retrieved. The retrieved data is used to modulate a carrier signal to produce a digital transmission signal, which is stored for later use, such that impairments in a signal from a traditional trusted unit are substantially removed, thereby minimizing uncertainty during later testing using such signal.

[0004] In accordance with one embodiment of the presently claimed invention, a method for generating a reference transmission signal for use in testing a communications receiver includes:

capturing a data packet transmission signal containing a plurality of reference data;

digitizing the data packet transmission signal;

retrieving at least a selected portion of the plurality of reference data from the digitized data packet transmission signal to produce a plurality of retrieved data;

modulating a carrier signal with the plurality of retrieved data to produce a digital transmission signal; and

storing the digital transmission signal.

[0005] In accordance with another embodiment of the presently claimed invention, circuitry for generating a reference transmission signal for use in testing a communications receiver includes:

signal capture means for capturing a data packet transmission signal containing a plurality of reference data;

digitizer means for digitizing the data packet transmission signal;

first data retrieval means for retrieving at least a selected portion of the plurality of reference data from the digitized data packet transmission signal to produce a plurality of retrieved data;

signal modulator means for modulating a carrier signal with the plurality of retrieved data to produce a digital transmission signal; and

storage means for storing the digital transmission signal.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] Figure 1 illustrates a technique for capturing a wireless data signal indirectly for use in generating a reference transmission signal in accordance with one embodiment of the presently claimed invention.

[0007] Figure 2 illustrates another technique for capturing a data signal indirectly for use in generating a reference transmission signal in accordance with another embodiment of the presently claimed invention.

[0008] Figure 3 illustrates a technique for capturing a wireless data signal more directly for use in generating a reference transmission signal in accordance with another embodiment of the presently claimed invention.

[0009] Figure 4 illustrates a technique for capturing a wired data signal directly for use in generating a reference transmission signal in accordance with another embodiment of the presently claimed invention.

[00010] Figure 5 depicts a data signal having multiple data packets.

[00011] Figure 6 depicts a system for generating a reference transmission signal in accordance with one embodiment of the presently claimed invention.

[00012] Figure 7 depicts a method for generating a reference transmission signal in accordance with another embodiment of the presently claimed invention.

DETAILED DESCRIPTION OF THE INVENTION

[00013] The following detailed description is of example embodiments of the presently claimed invention with references to the accompanying drawings. Such description is intended to be illustrative and not limiting with respect to the scope of the present invention. Such embodiments are described in sufficient detail to enable one of ordinary skill in the art to practice the subject invention, and it will be understood that other embodiments may be practiced with some variations without departing from the spirit or scope of the subject invention.

[00014] Throughout the present disclosure, absent a clear indication to the contrary from the context, it will be understood that individual circuit elements as described may be singular or plural in number. For example, the terms "circuit" and "circuitry" may include either a single component or a plurality of components, which are either active and/or passive and are connected or otherwise coupled together (e.g., as one or more integrated circuit chips) to provide the described function. Additionally, the term "signal" may refer to one or more currents, one or more voltages, or a data signal. Within the drawings, like or related elements will have like or related alpha, numeric or alphanumeric designators. Further, while the present invention has been discussed in the context of implementations using discrete electronic circuitry (preferably in the form of one or more integrated circuit chips), the functions of any part of such circuitry may alternatively be implemented using one or more appropriately programmed processors, depending upon the signal frequencies or data rates to be processed.

[00015] In accordance with the presently claimed invention, a method and apparatus for generating a desired test signal is provided. As modern test equipment begins to integrate both transmitter and receiver within a single housing (e.g., see commonly assigned, co-pending U.S. Patent Application No. ___________(atty. file 11602.00.0007), filed on even date herewith and entitled, "Integrated Radio Frequency (RF) Tester", the disclosure of which is incorporated herein by reference), it is possible to use the internal receiver to capture an actual signal from an existing known good sample of a DUT ("trusted unit"). Such signal captured by the receiver can then be demodulated or decoded using the software within the tester, since the software must be able to process its received signals in order to analyze them. As long as this capture is done at moderate or strong receive signal levels, few if any bit

errors should be expected due to noise or signal attenuation. Accordingly, the data bits are known, so a valid decoded data stream now exists within the tester. The transmitter software can then use the received bit pattern to generate an ideal representation of the received data stream. Since the transmitter within the tester will be of high quality, a high quality transmit signal can be produced, thereby ensuring minimal bit errors.

[00016] As a result, it is possible to create a replacement for a trusted unit often used in production test equipment by simply capturing the transmission signal of the trusted unit and having the test equipment recreate the bit patterns. This will allow necessary and appropriate test signals to be quickly created and consistently generated for use in a production environment as well as in a testing and debugging operation.

[00017] As discussed in more detail below, in accordance with the presently claimed invention, the desired signal is captured, following which the subject data is retrieved and any imperfections removed. The resulting desired data is then remodulated to produce a digital signal representing the desired reference, or test, signal. Such signal can then be stored for later and multiple uses.

[00018] Referring to Figure 1, one way to capture a known good signal is to indirectly receive (often referred to as "sniffing") the actual signal sent by a trusted unit 100 to a DUT 200. The trusted unit 100 has a baseband section 130 which provides the baseband data for the transmitter portion 110 as well as processes the baseband data received via the receiver portion 120. The DUT 200 includes similar baseband 230, transmitter 210 and receiver 220 portions. A transmitted signal emanating from the antenna 140 of the trusted unit 100 is received by the antenna 240 of the DUT 200, as well as the antenna 350 of the tester 300.

[00019] The received data signal is processed within a receiver 310 in the tester 300, and further processed by a demodulator section (e.g., digital signal processor) 320. As an integrated tester, the tester 300 also includes a modulator (e.g., digital signal processor) 340 and a transmitter 330 for generating test signals. A timing signal 400 from the baseband section 130 of the trusted unit 100 can also be provided for use in determining any necessary timing information between data packets contained within the received data signal. Such timing signal 400 also helps to identify the data signal received at the antenna 350 of the tester 300 as being that emanating from the trusted unit 100 as opposed to a data signal originating from the DUT 200.

[00020] Referring to Figure 2, an alternative technique for indirectly receiving the data signal from the trusted unit 100 involves the use of a power splitter or directional coupler 500 which will generally provide a more reliable signal path for conveying the desired signal from the trusted unit 100 to the tester 300.

[00021] Referring to Figure 3, another alternative technique is the direct reception of the data signal by the tester 300. This technique is similar to that depicted in Figure 1. However, without a DUT 200 involved, it is possible that the tester 300 can be placed in closer proximity or more direct line of sight alignment with the signal coming from the trusted unit 100.

[00022] Referring to Figure 4, perhaps a more reliable technique is a direct wired connection 200 between the trusted unit 100 and the tester 300.

[00023] Referring to Figure 5, the data signal 11 transmitted by the trusted unit 100 will often include multiple data packets DP, among which one data packet DP(n) may be the

data packet of interest, as opposed to other data packets DP(n-1), DP(n+1). Accordingly, as mentioned above, it may be desirable, and sometimes necessary to also receive some form of timing information along with the data signal 11 so as to ensure that the desired data packet DP(n) is selected and processed.

[00024] Since the signal 11 has been received from a known good unit, i.e., the trusted unit, the data packets contained therein are known to be valid and could possibly be used for communication with a DUT directly. However, the received signal may still have some impairments, which may affect the receiver of the DUT, thereby resulting in an excessive bit error rate (BER). Further, the power level and format of the received signal may not be directly compatible with the transmitter section of the tester, thereby causing some uncertainty about the signal being transmitted by the tester. For example, normally the signal must be scaled to a certain level so as to enable calibration within the tester, so significant post processing may be required to use the captured signal directly. Moreover, the captured signal may not be in the proper format, e.g., the receiver may use a sampled IF (intermediate frequency) receiver to capture the signal, while the transmitter of the tester uses a quadrature frequency up-conversion process. Accordingly, rather than using the captured signal directly, the signal is processed so as to retrieve the actual data contained within the data packet DP, i.e., in its pure digital (binary) form.

[00025] Referring to Figure 6, that portion 310a of the receiver responsible for capturing and processing the data packet signal 11 digitizes the data packet signal 11 with a digitizer 12 (e.g., analog-to-digital converter). The digitized signal 13 is then placed in some form of registers or data selectors 14 from which the desired data packet 15 is selected, e.g., in accordance with timing information 9 as noted above.

[00026] The desired data packet 15 is processed in a demodulator or decoder 16 so as to produce the actual data contained within the data packet 11. (Such demodulation or decoding removes any modulation or encoding, such as frequency shift keying, phase shift keying, pulse width modulation, Manchester encoding, return-to-zero encoding, non-return-to-zero encoding, among others well known in the art.) This binary data 17 is passed on to a data combiner 18 and a data selector 22 (e.g., a multiplexor). In the data combiner 18, the binary data 17 can be selectively altered with one or more bits 21 from a selection of error bits 20, thereby producing a binary signal 19 having one or more selected bits altered so as to selectively introduce bit errors as desired. In accordance with a data selection signal 7, the actual binary data 17 or altered data 19 is provided as the selected data signal 23 to a modulator or encoder 24 which provides an appropriately modulated or encoded signal 25 representing the selected data signal 23 with no signal impairments. This data signal 25 can then be stored, e.g., in a memory 26, for later and multiple uses in testing DUTs. Hence, an ideal data signal becomes consistently available for later use(s) in testing multiple systems.

[00027] By retrieving and processing the received data packet signal 11 in this manner, since such retrieval and processing is offline, i.e., not done in real time during an actual test, any necessary processing on the part of the demodulator/decoder 16 and modulator/encoder 24 can be performed regardless of any complexities, thereby ensuring the creation of a good reference data signal for later use in tests.

[00028] Referring to Figure 7, a methodology for generating a reference transmission signal for use in testing a communications receiver in accordance with the presently claimed invention can be described as follows. In conformance with the discussion above, the first phase of operation 72 includes the capturing of the data signal. Following that, the next

operational phase 74 is the digitizing of the captured signal, followed by a phase 76 in which the actual data is retrieved (e.g., demodulated or decoded).

[00029] Following that, the next phase of operation 80 is the modulation or encoding of the retrieved data, or alternatively, an intermediate phase 78 in which one or more bit errors are introduced by the substitution of selected bits in the data stream, followed by the modulation or encoding phase 80. The next operational phase 82 is the storage of the modulated or encoded data signal for later and multiple uses in tests. Lastly, for each of such tests, the stored data signal is retrieved and transmitted in a signal transmission operation 84 for the actual tests.

[00030] Various other modifications and alternations in the structure and method of operation of this invention will be apparent to those skilled in the art without departing from the scope and the spirit of the invention. Although the invention has been described in connection with specific preferred embodiments, it should be understood that the invention as claimed should not be unduly limited to such specific embodiments. It is intended that the following claims define the scope of the present invention and that structures and methods within the scope of these claims and their equivalents be covered thereby.